Laser Induced Breakdown Spectroscopy (LIBS) for Surface and Subsurface Soil Characterization

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ABSTRACT

Needs

Contamination of the soil by metals, such as lead (Pb), chromium (Cr), copper (Cu), zinc (Zn), uranium (Ur) and beryllium (Be) is an area of great concern for government and industry. The characterization, monitoring and remediation of these soils is extremely expensive and time consuming due to the magnitude of the effort and the utilization of laboratory chemical analysis techniques. The present laboratory methods of evaluating environmental samples offer high sensitivity and the ability to evaluate multiple chemicals, but the time and cost associated with such methods often limit their effectiveness. For field investigations there is a need for techniques that can be used rapidly to generate quantitative and semi-quantitative screening data so that the remediation, health and safety plans can be effectively generated. During the actual cleanup, real-time instrumentation can be used to monitor progress. If soil is being removed and stored at another location, for example, hundreds of dollars per square yard can be saved by only removing contaminated soils.

Approach

In order to characterize metals contamination quickly and effectively to address the problems discussed above, SEA is developing a suite of field instruments and procedures based upon Laser-Induced Breakdown Spectroscopy (LIBS). The technique utilizes a focused, high peak power laser to initiate a plasma "spark" of the sample to be analyzed. The wavelengths and intensities of the light emission from the plasma are evaluated with a spectrometer to identify the presence and quantity of contaminants. The advantage of such a system is that the sample does not have to undergo rigorous preparation, as is common in laboratory processes, and the testing is done in the field, often without the creation of any waste that must be disposed.

The LIBS system can take several forms depending upon the problem to be addressed. Under this effort, SEA is developing an integrated LIBS/cone penetrometer system to perform subsurface characterization. In this deployment scheme, the LIBS hardware is located safely within the cargo section of the truck and the soil analysis is conducted at the tip of the penetrometer rod string. As the penetrometer rods are retracted, the LIBS system is used to "spark" the soil, thus a vertical map of the contamination can be produced at that location. A 3-D mapping can be conducted by moving the truck around the site. For surface and near-subsurface analysis, the LIBS hardware utilized in the CPT design can also be deployed via van. Soil samples, as would

be obtained by a split spoon grab sampling, can be brought to the LIBS system for on-site analysis. This type of system could then be exploited for near subsurface characterization. In order to conduct quick surface analysis, LIBS systems have been developed to be deployed via a man-portable backpack. The spectrometer, detector, batteries and electronics can be supported on a backpack and the laser can be embedded into a "staff" or "walking stick" that can be placed upon the sample surface for a discrete spot analysis. In this deployment scheme, the LIBS technician can simply walk over a contaminated site and produce a surface concentration map of the element of interest.

Project Description

The primary objective of this project is to develop an integrated LIBS/penetrometer system to analyze the heavy metals content of the subsurface. Under the Phase I effort of this program, SEA investigated the requirements and showed the feasibility of such a sensor. Under the present Optional Phase of the project, a field deployable prototype system was designed and fabricated. The penetrometer portion of the program will culminate with a field test at a DOE site.

In addition to the LIBS/penetrometer development and demonstration, SEA has been tasked to perform LIBS soil characterization at a FUSRAP site in Luckey, Ohio. This portion of the effort involves the use of backpack and truck mounted LIBS units to generate surface concentration maps of Be contamination. An optional portion of this program is to perform analysis on excavated soils to determine the overall volume of Be contamination.

Accomplishments and Future Work

The cone penetrometer system has been developed and will be undergoing field tests at Hanford to evaluate for uranium in the 300 Area and chromium in the 100 Area in November 1997. The system consists of 1) the LIBS hardware, 2) a high power laser delivery system, 3) an optical fiber spectral emission detection system, 4) a computer data acquisition system and 5) the penetrometer housing. In addition to hardware development, we developed a soil sample matrix to investigate the effect of soil type, grain size, moisture, and organic matter on the LIBS signal to account for various operating conditions. This data analysis is presently ongoing.

For the FUSRAP portion of this effort, the backpack LIBS is presently being deployed to monitor the surface concentrations of Be. SEA was responsible for developing the field procedures and integrating the use of the LIBS instrument into an ongoing characterization effort. This effort marks the first use of a LIBS backpack instrument in the field.

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